Using formative feedback to identify and support first-year chemistry students with missing or misconceptions.

Gwen Lawrie, School of Chemistry and Molecular Biosciences, Anthony Wright, School of Education, University of Queensland, Madeleine Schultz and Timothy Dargaville, School of Chemistry, Physics and Mechanical Engineering, Queensland University of Technology, Glennys O’Brien and Simon Bedford, School of Chemistry, The University of Wollongong, Mark Williams and Roy Tasker, School of Science and Health, The University of Western Sydney.

Abstract

Students entering tertiary studies represent a diverse range of prior experiences in their academic preparation for tertiary chemistry so academics need tools to enable them to respond to issues in diversity in conceptual models possessed by entering students. Concept inventories can be used to provide formative feedback to help students identify concepts that they need to address to improve construction of subsequent understanding enabling their learning.

Modular, formative learning activities that can be administered inside or outside of class in first-year chemistry courses have been developed. These activities address key missing and mis-conceptions possessed by incoming student. Engagement in these learning activities by students and academics will help shift the culture of diagnostic and formative assessment within the tertiary context and address issues around the secondary/tertiary transition. This diagnostic/intervention framework is currently being trialed across five Australian tertiary institutions encompassing a large heterogeneous sample of students.

Background

Constructivist learning environments are most effective when the learner and teacher are both aware of the existing conceptual models that learners possess to enable them to extend and apply their understanding rather than resort to rote learning (Taber, 2001). As students transition into, and engage in, the new tertiary learning environment it is important to assist them to maximise the effectiveness of their learning which requires measurement or diagnosis of their existing conceptual understanding. One of the challenges in teaching chemistry is to encourage students to recognise their existing knowledge and conceptual understanding and then apply it in new learning situations (Schraw et al, 2006).

A typical Australian tertiary first-year chemistry cohort is characterized by large numbers (300-1500) of students who represent a diverse range in academic abilities, interests, and motivations for learning. Students can be enrolled in one of approximately forty possible programs of study that require chemistry, for example, engineering, medicine, pharmacy, dentistry and other health sciences. Many students will have completed secondary chemistry studies however and many students enrol with no prior secondary chemistry experience. This
diversity in chemistry conceptions possessed by students provides a unique opportunity to research and develop mechanisms to differentiate learning support for students at risk of failing in tertiary chemistry studies.

In this Office of Learning and Teaching project, academics in five universities across three states are collaborating to develop and implement a diagnostic and intervention activity framework to provide support to entering first-year students who have poorly formed conceptions in chemistry. We will report the outcomes of the first stage of the intervention and the challenges that arose during the process.

Chemistry concept inventories (CCI) are multiple choice tests that have been considered widely as a route to exploring students existing conceptions (Mulford & Robinson, 2002; Othman et al, 2008; Potgieter et al, 2008; Pavelich et al, 2004). Despite the published outcomes of concept inventories in terms of common misconceptions, there are few interventions or learning tools that a teacher can apply as an intervention for students to address incorrect or naive mental models. We are addressing this deficiency by assembling web-based tools that academics can apply as appropriate in their own tertiary contexts. The role of feedback linked to formative assessment as the core part of the intervention tool is illustrated in Figure 1 below.

![Figure 1: A schematic representation of the mechanism for feedback and the process of scaffolding through the intervention module.](image)

Feedback is particularly important for first-year students because they are coming to terms with the change of environment, expectations, teaching approaches and forms of assessment. In this context, Hattie and Timperley’s three questions (Hattie & Timperley, 2007) are particularly relevant: “Where am I going?”, “How am I going?” and “Where to next?” Formative assessment is critical to “How am I going?” and the feedback is just as valuable for the instructor as for the students to align teaching and learning activities.

The efficacy of matching diagnostic assessment with a post-test intervention has been established in chemical education research (Treagust et al., 2011, Heredia et al, 2012). The challenge is to engage students in their individual feedback and enable them to respond to it, especially in the large class setting. The scale and instructor/student ratios make it imperative to develop a student’s ability to reflect on and self-regulate their own learning. Useful guidelines for the use of feedback to promote self-regulation (Nicol & Macfarlane-Dick, 2006) includes the clarification of good performance, facilitation of self-assessment and encouraging feedback and dialogue. In the pilot intervention of this project, student perception and utilization of individual feedback from the diagnostic is being explored. In this study, once alternative conceptions have been identified students are placed in
environments where they can challenge their conceptions through alternative frameworks (Chi et al, 1994).

**Context and intervention**

Seven first-year chemistry course coordinators and a secondary teacher educator, representing multiple tertiary institutions across Queensland and New South Wales, comprise the core project team. A concept inventory diagnostic inventory test has been assembled from multiple literature instruments and also informed with pilot data collected between 2009–2012 (Schultz & Lawrie, 2011; Lawrie et al, 2012). Questions are clustered around a core concept in sets of five and the combination of responses that students opt for are used to identify key misconceptions. The five core conceptual clusters that will be addressed in this project are: phase changes, energy transfer, solutions, conservation of matter and equilibrium. These concepts are tested at the level encountered in secondary chemistry (or junior science) and are common to the syllabi across multiple Australian states.

The workflow of the pilot intervention in semester 1, 2013 involves:

- **Week 1:** The diagnostic instrument will be delivered online across all participating institutions.
- **Week 3:** Students will receive individual feedback indicating the concepts they are performing well on and those that they need to address to enable success in tertiary chemistry.
- **Week 3-4:** A link to a web-based activity that addresses the basis of a misconception will be made available to the student and their progress monitored by concept check questions.
- **Weeks 4-13:** Evaluation of longer term impacts through formative and summative assessment of related concepts.

Evaluation of the intervention includes student interviews and learning outcomes at the end of semester 1. The experiences of the academics involved in the delivery of the interventions have been collated to enable improvement in the next iteration of the study. One of the key challenges has been to deliver activities that both engage students in active learning while adjusting their mental models. The pilot intervention, which addresses the concept of phase changes, combines interactive simulations with everyday phenomena inviting students to reflect on reasonable explanations for phenomena. Cognitive conflict (dissonance) has been applied as a strategy to encourage students to critically appraise their conceptual models (Linenberger & Lowery Bretz, 2012). Students have been challenged to consider whether their conceptions are valid.

We are placing a spotlight on articulation between the secondary and tertiary contexts which will enable us to inform practice in both sectors particularly in the context of the impending National Curriculum (ACARA, 2011) and academic standards development (LTAS, 2011).

**Key questions for discussion at nuts and bolts session**

In this session, the framework, evaluation and the outcomes of the pilot diagnostic and intervention from semester 1 will be presented to highlight the challenges in engaging first-year chemistry students in self-regulated learning based on formative feedback. Attendees in this FYHE “nuts and bolts” session will be invited to contribute to the discussion of the following questions.
Input from participants is sought in response to the following key questions:

- What is the optimal format for delivering formative feedback to first-year students that they will act on?
- How can we maintain student engagement in self-regulated activities that encourage critical thinking?

References


